2021

Guidances for Underwater Radiated Noise

GC-37-E

KR

APPLICATION OF "GUIDANCES FOR UNDERWATER RADIATED NOISE"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which the application for Classification Survey is submitted to the Society on or after 1 July 2021.

CONTENTS

CHAPTER 1 GENERAL

Section 1 General

101. Application

1. This guidances apply to new and existing ships that have applied for the optional notation URN (Underwater Radiated Noise) for the ship's underwater radiated noise.

102. Definitions

1. For general terms not otherwise defined in this guidances, refer to ISO 18405 and the standard series ISO 17208.
2. **Shallow water** means a water depth shallower than 150m.
3. **Deep water** means a water depth deeper than 150m.
4. **Background noise** means the noise of all noise sources (bio and non-bio) other than the ship being measured, including its own noise or equipment noise.
5. **Closest point of approach (CPA)** means the point where the horizontal distance from the ship reference point of the ship under test to the hydrophone is the closest.
6. **Ship reference point** means the point indicating the position of the ship during the measurement of underwater radiation noise, and in this guidance, it means the acoustic center.
7. **Data window length (DWL)** means the distance between the start position and end positions of data recording.
8. **Underwater sound pressure level (L_p)** means to the mean squared sound pressure level measured with an underwater hearing device, and is expressed in units with the following formula. The underwater sound pressure level is determined by 1/3 octave band (1/3 octave band filter in accordance with IEC 61260) over the frequency range of 10 Hz to 50,000 Hz.

$$L_p = 20\log_{10}\left(\frac{p_{rms}}{p_0}\right) \qquad (dB)$$

p_{rms} : root-mean-square sound pressure
p_0 : reference sound pressure (1 μPa)

9. **Underwater radiated noise level (L_{RN})** means the value obtained by converting the measured underwater sound pressure level to the underwater sound pressure level at a reference distance (1 m) from the ship's reference point.
10. **Measurement uncertainty** means the expected variance of measured underwater radiated noise levels. It is expressed in decibels for a 1/3 octave band using a given measurement method (average time, bandwidth-time product, etc.).
11. **Ship length** means the distance (m) measured on the waterline at the scantling draught from the fore side of stem to the after side of rudder post in case of a ship with rudder post, or to the axis of rudder stock in case of a ship without rudder post or stern post. Ship length is not to be less than 96 % and need not be greater than 97 % of the extreme length on the waterline at the scantling draught. In ships without rudder stock (e.g. ships fitted with azimuth thrusters), ship length is to be taken equal to 97 % of the extreme length on the waterline at the scantling draught.
12. **Normal operation mode** means the condition in which the ship's propeller output and all other machinery are operated under contractual normal seagoing conditions.

13. **Quiet operation mode** means the condition in which the ship's propeller output and all other machinery are operated under the adjusted operation conditions of the ship's propellers to operate in environmentally sensitive areas (i.e. underwater radiated noise control areas). In the case of measuring underwater radiated noise in quiet operation mode, the operating conditions of propeller output and other machinery are to be specified in the underwater radiated noise measurement plan.

103. Class notations

1. Ships whose owner applies for inspection and that meet the requirements of this guidance may be assigned one of the classification notations of **URN-T(XX)** or **URN-Q(XX)**. URN-T(XX) is the notation for normal operation mode, URN-Q(XX) is the notation for quiet operation mode, and XX is the ship speed (knots) corresponding to the propeller output at each mode.

Section 2 Plans and Documents

201. General

1. For ships to be inspected, the underwater radiation noise measurement plan specified in **202. 1** below is to be submitted to the Society for approval. In addition, after the underwater noise measurement in the presence of the Surveyor of the Society has been carried out, a report of the measurement results including the items specified in **202. 2** below is to be submitted to the Society for approval. If deemed necessary by the Society, the submission of additional documents may be requested.

202. Plans and documents to be submitted

1. Underwater radiated noise measurement plan

A detailed measurement plan developed for the measurement of the underwater sound levels of the ship prior to the measurement. The plan is to include the following.

(1) Ship Information and Identification of Participants
  (A) Ship information, including ship's name, hull number, class number, etc., as well as the ship's main dimensions
  (B) Identification of participants, including person in charge of test, owner representative, shipyard representative and test personnel

(2) Measurement Test Site
  (A) Geographical location, water depth and sea bottom conditions
  (B) Wind speed and sea surface conditions for planned tests
  (C) Weather conditions (Weather conditions are to be predicted based on a reliable weather forecast web site/service.)

(3) Measurement System
  (A) Hydrophones (number, type and model) and deployment (method and hydrophone depths, including sketches to show the deployment configuration)
  (B) Distance measurement system
  (C) Calibration plans and current calibration certificates of all measurement instruments
  (D) Detailed information of data acquisition and recording system to be used

(4) Sea Test
  (A) Description of measurement procedure
  (B) Test agenda including test schedules, a description of the planned test courses (including sketches to show the sailing course and identification of the closest point of approach and various starting and ending points) and the operating profile which includes the speed, and loading condition of the test ship for each test course
  (C) Methods to be used for monitoring the test site environment, checking the ship operation conditions and other auxiliary measurements

(5) Post Processing/Analysis
  (A) Description of post processing and analysis procedures of measured underwater sound data
  (B) Methods for evaluating the measurement uncertainty

2. Underwater radiated noise measurement report

A ship-specific underwater radiated noise measurement report containing test information, description of data processing, analysis of measured underwater sound data and compliance evaluation against applicable criteria. The report is to contain the following.

(1) Introduction
  (A) Objective of Measurement
  (B) Ship Characteristics
    (a) Ship Particulars
    (b) Propulsion Characteristics
    (c) Propeller Information
  (C) Underwater Noise Criteria
(2) Underwater Noise Measurement
  (A) Measurement Protocol
  (B) Test Period and Site
    (a) Location and Time of Measurement
    (b) Environmental Conditions
  (C) Instrumentation
    (a) Hydrophones and Signal Conditioning (Calibration of Hydrophones)
    (b) Distance Measurement System
    (c) Data Acquisition/Processing System (Data Sampling Rate)
  (D) Test Course and Maneuvering Configuration
    (a) Nominal Closest Point of Approach
    (b) Test Course and Test Runs
    (c) Ship Operating Conditions
    (d) Background Noise Measurements
    (e) Measurement Procedure
  (E) Other Auxiliary Measurements and Data
  (F) Deviations from Approved Measurement Plan
  (G) Data Sheet with Surveyor Signature
(3) Data Processing
  (A) Data Processing Procedure
  (B) Data Quality Assessment
  (C) Background Noise Adjustments
  (D) Distance Adjustments
(4) 1/3 Octave Band Data Analysis
  (A) Results for Each Hydrophone and Each Test Run
  (B) Results for Multiple Hydrophones and Multiple Runs
  (C) Verification against Defined Criteria
(5) Narrow-band Analysis (if applicable)
(6) Summary ⚓

CHAPTER 2 CLASSIFICATION SURVEYS

Section 1 General

101. General

1. The requirements not specified in this Chapter are to comply with those specified in **Pt 1** of **Rules for the Classification of Steel Ships**.

Section 2 Test and Inspection

201. General

1. In cases where a ship is to be surveyed in accordance with the Guidance, it is the responsibility of the Owner to notify Surveyors of the locations where they wish to undergo the relevant survey.
2. Applicants for surveys are to arrange supervisors who are well conversant with all of the survey items required for the preparation of such surveys and who are able to provide all assistance necessary per Surveyor request during such surveys.
3. Surveys may be suspended in cases where necessary preparations have not been made, no appropriate supervisor is present, or the Surveyor considers that the safety needed for the execution of the survey is not ensured.
4. In cases where repairs are considered to be necessary as a result of surveys, Surveyors are to notify survey applicants of their findings. Applicants, upon receiving such notification, are to obtain Surveyor verification after carrying out any such repairs.

Section 3 Periodical Surveys

301. On board installation and operation survey

1. Periodical Surveys are to be carried out at the Annual Survey, Intermediate Survey and Special Survey.
2. During Periodical Surveys, the non-existence of any alternations which may affect the underwater radiated noise level is to be confirmed. Additional underwater radiated noise measurements may be required in cases where deemed necessary by the Society in order to ascertain whether the relevant requirements given in the Guidance are satisfied.

Section 4 Occasional Surveys

401. Annual Surveys

1. Occasional Surveys are to be carried out on the following occasions at times other than Initial Surveys or Periodical Surveys:

   (1) In cases where any conversion affecting the underwater radiated noise of a ship are carried out.
   (2) In cases where any applications for surveys are submitted by owners.
2. Occasional Surveys are to be carried out and underwater radiated noise levels are to be confirmed as complying with those specified in the Guidance. ⚓

CHAPTER 3 UNDERWATER RADIATED NOISE MEASUREMENT

Section 1 General

101. General

1. The measurement and result analysis are to be performed in accordance with the requirements in **Sec.2** to **Sec.5**, and the criteria specified in **Sec.6** are to be satisfied.
2. Measurement of underwater radiation noise is to be performed by the service supplier registered with the Society.

Section 2 Instrumentation

201. General

1. In order to quantify the underwater sound from a ship, three main instrumentation components are required: (1) hydrophone and signal conditioning, (2) data acquisition, recording, processing and display system, and (3) distance measurement system.

202. Hydrophone and signal conditioning

1. The hydrophone is to have the sensitivity, bandwidth and dynamic range necessary to measure the ship under test.
2. For underwater radiated noise measurement, three hydrophones that should be omni-directional across the required frequency range of 10 Hz to 50,000 Hz are required.
3. Hydrophones are to be laboratory calibrated every 12 months in accordance with IEC 60565 for all required 1/3 octave bands. When fixed hydrophones are used, the fixed hydrophone calibration is to be performed by a comparative measurement utilizing a calibrated underwater sound source every 12 months.
4. The sensitivity and directivity of the hydrophones is to be determined to within ±2 dB.

203. Data acquisition, recording, processing and display

1. The data acquisition, recording, processing and display system are to be capable of accurately acquiring, recording, processing and displaying data from the hydrophones.
2. These systems are to comply with the requirements of ISO 17208-1.

204. Distance measurement

1. Distance measurement is required to continuously determine the actual distance between the hydrophones and the ship reference point of the ship under test.
2. The distance measurement systems are to determine the horizontal distance from the sea surface position above the hydrophones (i.e. the device or buoy used to suspend the cable) to the ship reference point of the ship under test. The distance measurement device may utilize any method (e.g. optical, acoustical, GPS, radar) to achieve the required accuracy.
3. The distance measurement system is to be accurate in 10 m.
4. The hydrophone cable drift is not to exceed 5 degrees. If the drift angle does exceed 5 degrees, the drift angle is to be taken into account when determining the slant range.

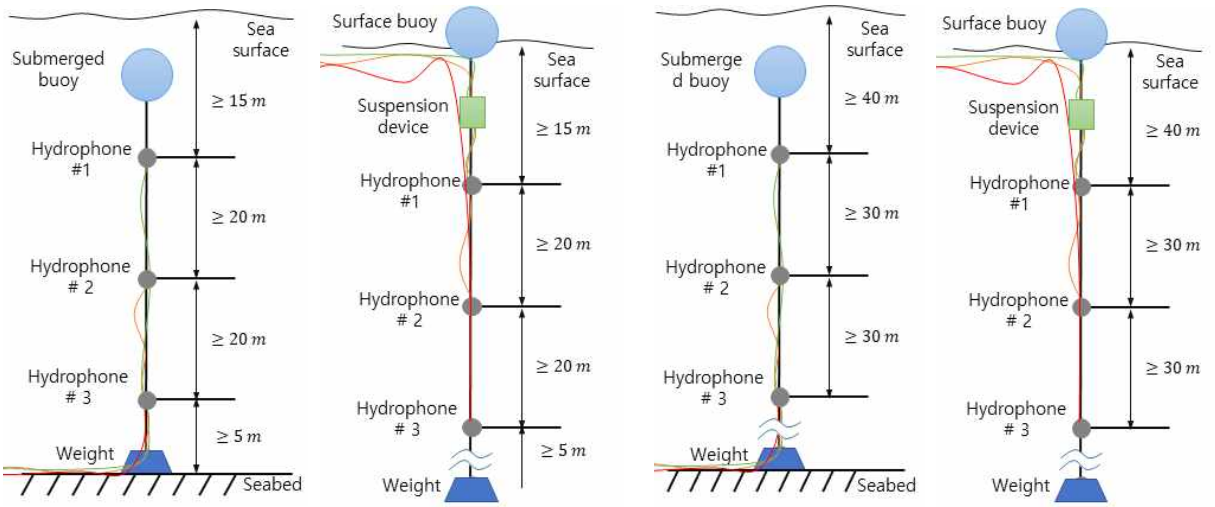
Section 3 Measurement Procedure

301. General

1. In order to perform an accurate measurement of a ship's underwater sound, several factors are to be addressed correctly, e.g. selection of an appropriate test site, proper deployment of hydrophones and proper operation of the ship under test.

302. Hydrophone deployment

1. Hydrophones are to be deployed as shown in **Figure 3.1** depending on the depth of the test site for underwater radiated noise measurement.
2. A deployment from a support vessel is to be avoided as it increases the measurement uncertainties. If a support vessel is operated, it is ensured that it is not affecting the measurement results.
3. In order to reduce hydrophone's directivity the orientation of the hydrophone is directed towards the seabed.



(a) bottom-anchored deployment(shallow water) (b) surface-suspended deployment(shallow water) (c) bottom-anchored deployment(deep water) (d) surface-suspended deployment(deep water)

Figure 3.1 Deployment of hydrophones

303. Ship operation and test scope

1. The structure of the ship's operation and test range is as shown in **Figure 3.2**.
   (1) The ship under test must pass a straight course to achieve the required distance (d_{CPA}) at closet point of approach. d_{CPA} is 200 m or one ship length, whichever is larger.
   (2) The data window length is from 200 m before arrival (start data) to 200 m after passing (end data) based on the closest point of approach.
   (3) The distance from the start test range location (COMEX) and the end test range location (FINEX) to the closest point of approach is to be 800m or more.

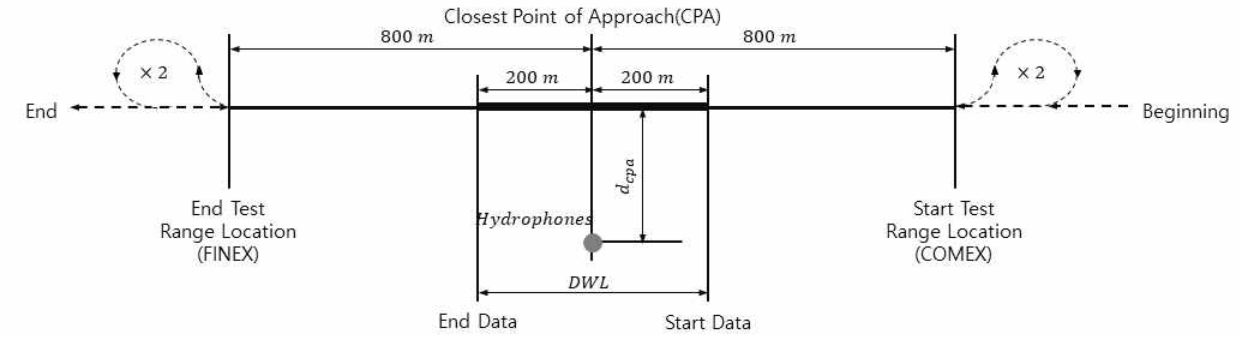


Figure 3.2 Ship operation and test range

2. Unless otherwise required by the ship's test plan, the ship under test is to maintain a constant speed, fixed engine conditions and minimum use of helm to maintain course until it has passed the end test range location.

304. Test sequence

1. The main propulsion and auxiliary machinery conditions are to be set up according to the conditions as specified in the approved measurement plan. The operating conditions are to be verified by the Surveyor.
2. The hydrophones and measuring instruments used in the data acquisition system are to be calibrated prior to the underwater noise measurements. The relevant instrumentation reference calibration certificates, together with the results of the field setup and calibration check are to be provided to the Surveyor.
3. The recognized service supplier for underwater noise measurement is to verify that all the measurement systems for carrying out the underwater radiated noise measurement are put in place and are functioning correctly.
4. At the start and the end of each measurement test run, the background noise measurement is to be carried out and recorded for at least 1 minute with the ship under test located at the farthest distance or at a distance of at least ≥ 2,000 m from the hydrophones, with the same hydrophone deployment and data acquisition methods.
5. During the recording of the background noise measurement, all main engines and generators are to operate only in idle conditions.
6. After the completion of the background noise measurement, the ship under test is to proceed to operate at the prescribed operating condition as specified in the approved measurement plan. The operating conditions such as the main and auxiliary engine output, ship speed, propeller RPM and nominal pitch, and loading condition are to be recorded accordingly.
7. Before the acoustic center of the ship reaches the start test range location, the intended operating conditions of the ship under test are to be achieved. Between the start test range location and the end test range location, the direction and ship operating conditions are to remain the same.
8. The data recording of the test measurement for the radiated underwater noise (where the mechanical output signal of the hydrophones is sent to the data acquisition system) is only to commence when the position of the acoustic center of the ship under test reaches the start data point (beginning of the data window period) and is to terminate when the acoustic center of the ship under test reaches the end data point (end of the data window period) as shown in **Figure 3.2**.
9. Distance measurements are to be recorded for the ship under test. These include the distance (d_{CPA}) at the closest point of approach, horizontal distance from the acoustic center of the ship to each hydrophone and the vertical distance between the depth of each hydrophone and the sea surface.
10. The ship under test is to make a "Williamson Turn" at the end test range location, where the ship will maneuver and prepare for the next set of runs on the alternate side of the ship repeating the

measurement procedure from **6** to **9**.

11. A complete test course requires the ship under test to perform two (2) repeated runs (with alternating approach) each on the port and starboard side of the ship under the same operating conditions.

Section 4 Measurement Condition

401. General

1. Sea trials are to be carried out with the ship in loaded or ballast condition. The actual condition during the measurements is to be recorded on the measurement report.

2. When measuring underwater radiated noise in shallow seas, the minimum depth of the test site should be at least 60 m. The seabed is to be as flat as possible.

3. Measurements are to be taken under conditions of Sea State 3 or less, as defined by Sea State Code of the World Meteorological Organization (WMO) and of Beaufort wind force scale 4 or less. If this cannot be achieved, the actual conditions are to be recorded on the measurement report.

4. Ship's course has to be kept constant, with rudder angle less than 2 degrees portside or starboard, for the duration of the measurement. If ship maneuvering is need, measurements are to be stopped until recovery of heading.

5. All machinery essential for ship operation is to operate under normal conditions throughout the measurement period. The list of machinery and equipment that are to operate normally during the measurement period is limited to the installed equipment.

6. Any deviations from operating conditions specified in the approved measurement plan is to be recorded in the measurement report.

402. Normal operation mode

1. During measurement, the propeller output is to be the normal seagoing speed of ship or at least 85 % of the maximum continuous rating (MCR) of the main engine.

2. Controllable pitch and Voith-Schneider propellers, if any, are to be in the normal seagoing position. For ships with special propulsion and power configurations, such as diesel-electric systems, the actual ship's design or operating parameters as defined in the ship's specifications will be used and are to be recorded on the measurement report.

403. Quiet operation mode

1. During measurement, propulsion system(conventional propeller, controllable pitch propeller, Voith-Schneider propeller, etc) is to be in the operating conditions specified in the approved measurement plan.

Section 5 Data Post-processing and Analysis

501. General

1. The underwater sound pressure measured by each hydrophone is to be subjected to post-processing steps such as background noise adjustments, sensitivity adjustments and distance adjustments.

2. The underwater sound pressure measured by each hydrophone should be collected while the ship reference point is in the data window, and analyzed by dividing it into 10 sub data windows as shown in **Figure 3.3**. Each sub data window should be a division of the data window as evenly as possible.

3. The underwater sound pressure level ($L_{p_{s+n}}$) collected in each sub data window is to be filtered and provided with a linear averaged root-mean-square value per 1/3 octave band from 10 Hz to 50,000 Hz.

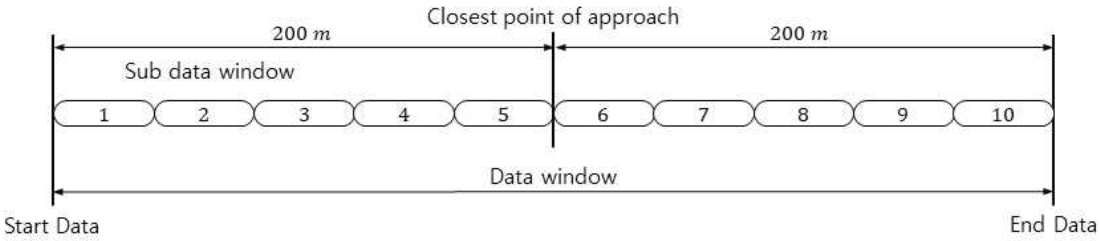


Figure 3.3 Composition of sub data window

4. The data post-processing described in **502.** through **505.** is to be performed per 1/3 octave band.

502. Background noise adjustments

1. A series of background noise data is collected at the beginning and end of each measurement run.

2. The difference ($\triangle L$) between the measured underwater sound pressure level ($L_{p_{s+n}}$) and background noise level (L_{p_n}) for each 1/3 octave band is determined by the following equation.

$$\triangle L = L_{p_{s+n}} - L_{p_n} = 10\log_{10}\left(\frac{p_{s+n}^2}{p_n^2}\right)$$

$\triangle L$: signal-plus-noise-to-noise level difference (dB) for each 1/3 octave band

p_{s+n} : root-mean-square sound pressure at the hydrophone (μPa). This value includes both the desired signal and undesired background noise

p_n : root-mean-square sound pressure of the background noise at the hydrophone (μPa)

$L_{p_{s+n}}$: root-mean-square sound pressure level (dB) with ship under test present for each run

L_{p_n} : background root-mean-square sound pressure level with the ship under test not influencing the measurement away 2,000 m from hydrophones (dB)

3. The underwater sound pressure level ($L^{'}{}_{p}$) of the ship under test is determined as follows depending on the magnitude of $\triangle L$.

(1) For $\triangle L > 10\ dB$

$$L_p^{'} = L_{p_{s+n}}$$

$L_p^{'}$: background noise adjusted root-mean-square sound pressure level of the ship under test (dB)

(2) For $3\ dB \leq \triangle L \leq 10\ dB$

$$L_p^{'} = 10\log\left[10^{\left(\frac{L_{p_{s+n}}}{10}\right)} - 10^{\left(\frac{L_{p_n}}{10}\right)}\right]$$

(3) For $\triangle L < 3\ dB$: The result of the measured underwater sound pressure level may be considered as invalid data, and the effectiveness of the data is to be evaluated on a case-by-case basis by the Society.

503. Sensitivity adjustments

1. Underwater sound pressure levels adjusted for background noise is to take into account the sensitivity of the hydrophone(s). The sensitivity adjustment of the hydrophone is performed according to the following equation.

$$L_p'' = L_p' + A_{SEN}$$

L_p'' : the unweighted root-mean-square sound pressure level after background adjustment (dB)
A_{SEN} : the adjustment for hydrophone sensitivities (between $\pm 2\,dB$)

504. Distance adjustments

1. In order to obtain the underwater radiation noise level at a reference distance of 1 m from the noise source, the transmission loss (TL) due to sound wave transmission in the water should be considered.
   (1) The transmission loss for each sub data window should be measured using the actual measured value at the test site. When measuring the transmission loss directly, a known noise source should be towed along the same path as the ship under test.
   (2) If it is not practical to follow above (1), the transmission loss can be calculated with the following simple propagation law.
   (A) For water depth $<$ 100 m

$$TL = 19\log\left(\frac{d_{Total}}{d_{ref}}\right)$$

d_{Total} : the total distance from the reference point (center of sub data window) of the ship under test to each of the hydrophones (m)

$$d_{Total} = \sqrt{d_{vertical}^2 + d_{horizontal}^2}$$

d_{ref} : reference distance (=1 m)

   (B) For water depth $\geq$ 100 m

$$TL = 20\log\left(\frac{d_{Total}}{d_{ref}}\right)$$

2. The underwater sound pressure level (L_{RN}) for each hydrophone, measurement run and sub data window is determined by the following equation.

$$L_{RN}(r,h,i) = L_p''(r,h,i) + TL(r,h,i)$$

$L_{RN}(r,h,i)$: the underwater radiated noise level for rth run (r=1~4), h hydrophone (h=1~3) and ith sub data window (i=1~10) ($dB\,re\,1\,\mu Pa\,@\,1\,m$)
$L_p''(r,h,i)$: the unweighted root-mean-square sound pressure level after background adjustment for rth run, h hydrophone and ith sub data window ($dB\,re\,1\,\mu Pa$)
$TL(r,h,i)$: the transmission loss for rth run, h hydrophone and ith sub data window (dB)

505. Determination of the final underwater radiation noise level

1. The level of underwater radiated noise for each run and hydrophone is determined by the following equation.

$$L_{RN}(r,h) = \frac{\sum_{i=1}^{10} L_{RN}(r,h,i)}{10}$$

$L_{RN}(r,h)$: the underwater radiated noise level for rth run (r=1~4) and h hydrophone (h=1~3) $(dB\,re\,1\mu Pa\,@1m)$

2. The underwater radiation noise level for each operation is determined by the following equation.

$$L_{RN}(r) = 10\log\left[\frac{1}{3}\sum_{h=1}^{3} 10^{\frac{L_{RN}(r,h)}{10}}\right]$$

$L_{RN}(r)$: the underwater radiated noise level for rth run (r=1~4) $(dB\,re\,1\mu Pa\,@1m)$

3. The final underwater radiation noise level of the ship under test is determined by the following equation.

$$L_{RN} = \frac{1}{4}\sum_{r=1}^{4} L_{RN}(r)$$

L_{RN} : the final underwater radiated noise level for ship under test $(dB\,re\,1\mu Pa\,@1m)$

Section 6 Criteria

601. General

1. The final underwater radiated noise level of ship under test calculated in **505. 3** are to satisfy the acceptance criteria of underwater radiated noise level for the relevant operating mode in accordance with **Table 3.1** and **Figure 3.4**. ⚓

Table 3.1 Acceptance criteria of underwater radiated noise level (dB)

Frequency range	Normal operation mode (notation : URN-T(XX)[1])	Quiet operation mode (notation : URN-Q(XX)[1])
10 Hz ~ 100 Hz	-5log(f/10)+178	-3log(f/10)+168
100 Hz ~ 1,000 Hz	-5log(f/100)+173	-3log(f/100)+165
1,000 Hz ~ 50,000 Hz	-12log(f/1000)+168	-12log(f/1000)+162

note
(1) XX means the ship speed (knots) corresponding to the propeller output for each operation mode of the ship under test and rounded off to the nearest decimal point.

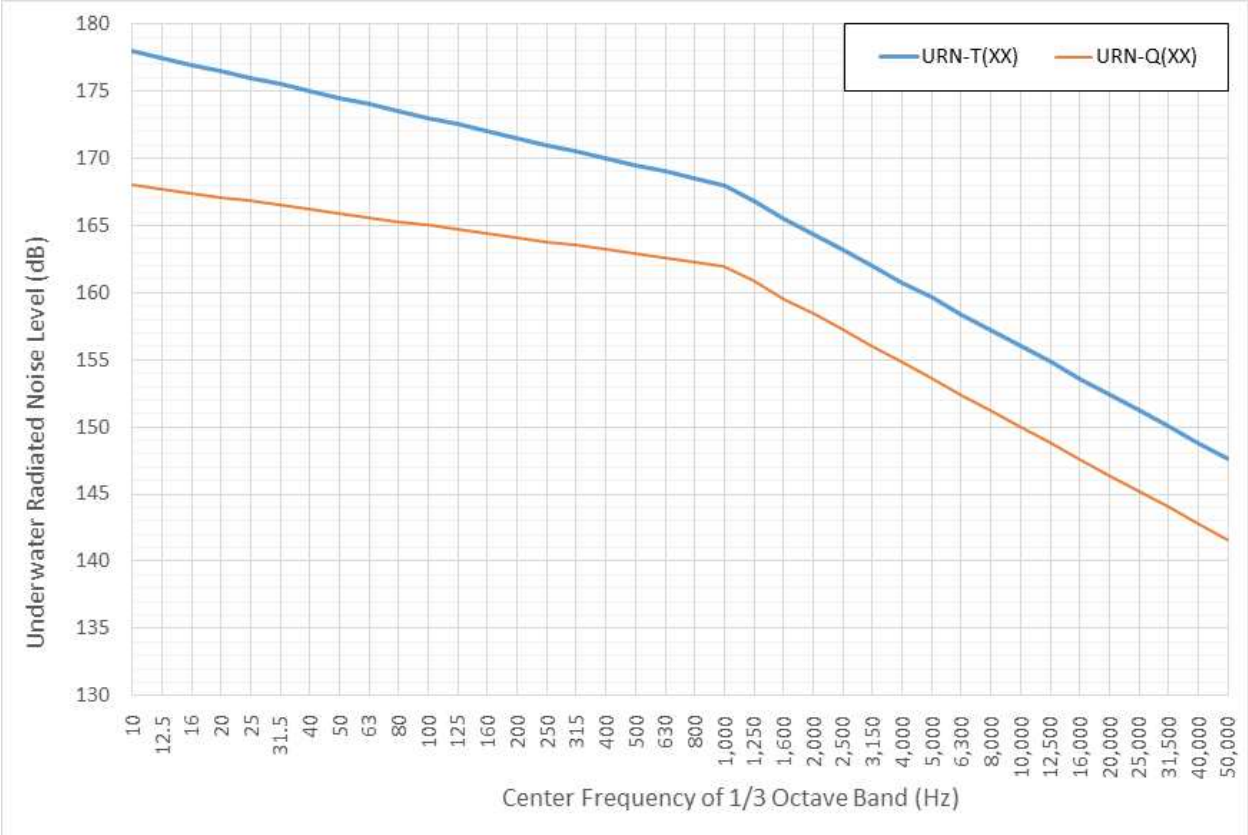


Figure 3.4 Acceptance criteria of underwater radiated noise level (graph)

GUIDANCE FOR UNDERWATER RADIATED NOISE

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